CUSTOM FITTED HELMET AND METHOD OF MAKING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application Serial No. 60/432,193 filed on December 6, 2002, which provisional patent application is incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The invention relates to a method of making a custom fitted helmet. More particularly, it relates to a method for making a custom fitted helmet having an impact energy absorbing liner having an inner surface that substantially conforms to the shape of the wearer's head.

Description of Related Art

[0003] Helmets having an impact energy absorbing liner are known for all sorts of applications, including cycling, football and other contact sports, medical intervention for persons prone to seizures, industrial protection such as for manufacturing and construction workers, military and other aircraft pilot protection, etc. In all of these applications, the impact energy absorbing liner is designed to absorb and/or dissipate energy from an impact to the outer shell of the helmet before it is transmitted to the wearer's head. In this manner the wearer's head is at least partially shielded or protected from what otherwise would be the full impact force resulting from the impact.

[0004] Conventionally, helmets are supplied in a plurality of standard sizes, e.g., large, medium, small. Sometimes the standard sizes are based on average head circumference, e.g. 14, 14.5, 15, 15.5, 16, inches, etc. A problem with this method of sizing helmets is that the helmets are sized based on universal standards that are not specific to any individual who will actually wear and depend on the helmet for head protection. While a standard sized helmet may provide adequate protection in some instances, it is not fitted to the unique shape and contour of the particular wearer's head, and therefore is prone to fit too tightly in certain aspects or along certain locations of the head while fitting too loosely in others. A too loosely fitting helmet can be as or nearly as catastrophic during an impact as wearing no helmet at all, because the initial impact against the outer helmet shell can be transferred to the head during a second impact between the head and the

loosely fitting interior surface of the helmet. Whereas a too tightly fitting helmet is uncomfortable to the wearer and can actually cause traumatic injury.

[0005] Currently, "off-the-shelf" helmets are fitted so that they fit snugly in the tightest dimension of the head – this could be from front to back, or it could be from side to side. The other dimension (front to back or side to side) is then looser - often with a gap of ½ inch or more on each side. This gap is often filled with non-energy- absorbing foam. As an example, a high performance ski helmet typically has approximately 1 inch of energy-absorbing polymer. The ½ inch of unused space on each side of the helmet comes at a high price from an energy absorbing standpoint, because even at moderate impact speeds (e.g. 6 m/s) that extra ½ inch of energy-absorbing foam would result in about a 30% improvement in g-force attenuation prior to reaching the wearer's head. At higher speed impacts the improvement would generally be higher due to the fact that thinner foam will 'bottom' out sooner as impact speed increases.

[0006] For these reasons, it is important and desirable that the inner surface of the helmet fit as uniformly and snugly as possible about the shape and contour of the individual wearer's head, without being so tight as to result in discomfort or injury. Conventional methods of making a custom fitted helmet include providing a preformed elastomer sack on the inner surface of a helmet shell, and then placing this assembly over a wearer's head with a shell cap placed in between the head and the elastomer sack. The purpose of the shell cap is to approximate the thickness of a subsequently-applied impact absorbing liner and to ensure there is sufficient space for such a liner between the elastomer sack (once rigidized) and the wearer's head within the helmet shell. In this method, the part of the helmet that actually will contact the wearer's head is not custom fitted to the head, therefore this helmet is subject to similar loosely and tightly fitting regions as described above. Other methods are known where an expandable foam is provided to expand in a pouch adjacent the wearer's forehead, but the remainder of the head-contacting regions are not custom fitted to the wearer's head. Further, in this method foaming is actually performed adjacent the wearer's head which is cumbersome to perform, and uncomfortable for the wearer.

[0007] Conventionally, helmets have been fit to a wearer's head either by shimming the inside of the helmet using energy-absorbing or comfort fitting foam pieces of varying thickness until the proper fit is achieved, or by installing a series of foam pieces of different thickness to provide a proper fit. There are two disadvantages of these methods: 1. It is difficult when fitting a helmet to know when you have achieved the proper fit. It is a trial and error process that requires more training than is typically available in retail stores. An improperly fitted helmet can lead to

serious consequences. 2. Energy-absorbing foam is more effective if it is in one piece. The reason for this is that a significant amount of energy is absorbed in the foam by pumping air through foam – the larger the piece of foam, the longer the path the air must take, and the better the energy-absorption. If the foam is in several layers or discrete pieces, it is easier for the air to escape and the energy-absorption properties are reduced.

[0008] Some manufacturers attempt to fit their helmets to wearer's heads using "fitting pads" of highly compressible foam that has no appreciable energy-absorbing capability. These fitting pads help keep the helmet tight on the head rather than provide an additional layer of energy-absorptive material. As will be apparent from the above discussion, the use of any more than a minimum of fitting-foam is a waste of critical space in a helmet that could be used to absorb additional energy which could save a life or eliminate a debilitating brain injury.

[0009] Still another approach is to use inflatable air bladders that when inflated properly can provide enough pressure to hold the helmet firmly on the head, yet not so much pressure that the helmet fit is uncomfortable. The air bladders, however, are not energy absorbing in the traditional sense, and again, the extra space that they take could be used for energy-absorption.

[0010] There is a need in the art for a method of making a custom fitted helmet that is economical and comfortable to the wearer, where the energy absorbing liner that actually contacts the wearer's head is snugly and uniformly fitted to the shape and contour of the head.

SUMMARY OF THE INVENTION

[0011] A method of making a helmet that is custom-fitted to a wearer's head is provided. The method includes the steps of positioning a shape-forming means over the wearer's head, and hardening the shape-forming means to provide a hardened headform that substantially conforms to the shape of the wearer's head.

[0012] A helmet that is custom fitted to a particular wearer's head is also provided. The helmet has an impact energy absorbing liner which is custom made such that it has an inner surface substantially conforming to the shape of the wearer's head.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Fig. 1 is a side view of a beanie cap for preparing a headform that can be used to mold an energy absorbing liner for a helmet according to the invention having an inner surface

substantially conforming to the shape and contour of a person's head.

[0014] Fig. 2 is a side view of a person's head to which the beanie cap of Fig. 1 has been applied and rolled down and/or stretched over, substantially conforming to the shape and contour of the person's head.

[0015] Fig. 3 is a side view of the person's head from Fig. 2 prior to application of the beanie cap, and showing a barrier applied over the person's head according to the invention, and also showing a piece of flexible tubing attached along the centerline of the rear of the person's head as a scissor guide.

[0016] Fig. 4 is a top plan view of a heat-softenable plastic sheet that can applied over a person's head and used to make a headform according to the invention for subsequently molding an energy absorbing liner for a helmet having an inner surface substantially conforming to the shape and contour of the person's head.

[0017] Fig. 5 is a top plan view of the heat-softenable plastic sheet of Fig. 4, shown positioned atop a person's head prior to folding the individual elements over the head to conform to the head's shape.

[0018] Fig. 6 is a side view of the heat-softenable plastic sheet of Figs. 4-5, shown positioned over and substantially conforming to the shape and contour of the person's head.

[0019] Fig. 7 is a side view of a person's head over which a curable tape has been wrapped to provide a headform according to the invention for subsequently molding an energy absorbing liner for a helmet having an inner surface substantially conforming to the shape and contour of the person's head.

[0020] Fig. 8 is a side view of a person's head having a hardened headform substantially conforming to the shape and contour of the person's head which was made using the beanie cap of Figs. 1-2, where a tight fitting elastic hood has been applied over the head prior to application of the beanie cap to protect the person's eyes, hair and scalp.

[0021] Fig. 9 is a schematic representation of an energy absorbing liner forming operation where a "male" mold member is suspended above a universally adjustable "female" mold member to define a molding space therebetween for molding an energy absorbing liner according to the invention.

[0022] Fig. 10 schematic side view of the "male" and "female" mold members from Fig. 9 shown in a molding position and defining the molding space for the energy absorbing liner therebetween.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

[0023] As used herein, when a range such as 5 to 25 (or 5-25) is given, this means preferably at least 5 and, separately and independently, preferably not more than 25.

[0024] The method of the present invention includes first making a headform that conforms to the shape of the wearer's head. The headform is made by positioning or wrapping an appropriate shape-forming means over and against the wearer's head. When the shape-forming means is applied to the head, it is in a softened or flexible state such that it can bend or flex or stretch to conform to the unique contour of the individual head to which it is being applied. Once the shape-forming means has been applied and conformed snugly to the shape and contour of the individual's head, it is hardened or rigidized such that it is no longer soft or flexible, thereby yielding a hardened headform 60 that conforms or substantially conforms to the shape and contour of the wearer's head.

[0025] Once hardened, the headform is carefully removed from the wearer's head so as not to break or deform the hardened headform, except for a scissor cut which may be employed to aid removal of the headform, as described below. This headform is then used (in a manner described below) to mold (or to prepare a mold for) an impact energy absorbing liner for a helmet that has an inner surface conforming or substantially conforming to the unique shape and contour of the head from which the hardened headform was made.

[0026] As used herein, the shape-forming means can be a stretchable beanie cap that is coated or impregnated with a curable polymeric material, a heat-softenable plastic sheet, or a strip or plurality of strips of curable tape that are wrapped about the wearer's head to provide a headwrap. Each of these is now described in detail.

[0027] Referring to Fig. 1, a stretchable beanie cap 10 according to a preferred embodiment of the invention is shown. The beanie cap 10 is made from an elastic material such that it is stretchable and recoverable. By recoverable, it is meant that if stretched from its relaxed state, the beanie cap 10 will tend to return to its initial shape at rest once the external stretching force has been removed in its uncured state. This is important to ensure that the beanie cap 10 conforms to the unique curvature and contour of a wearer's head after it has been stretched thereover; i.e. to

ensure the beanie cap 10 is snugly and elastically retained against the shape of the head over its entire surface of contact.

[0028] The beanie cap 10 can be made from an elastic polymeric fabric, such as the conventional Spandex™ or Lycra™ fabrics known in the art, alternatively glass fibers and fabrics can be used. In a preferred embodiment, the fabric used in beanie cap 10 is a knitted polyester fabric. Typically it is either knitted or assembled with fabric cut on the bias so the fabric has an elastic property and can stretch so as to conform tightly to the head and accommodate the variations in head shapes. The beanie cap 10 is coated, preferably impregnated or saturated with a curable polymeric material, such as a curable polymer resin, that cures to a hardened state. In a preferred embodiment, the curable material is a moisture or water curable polymer that cures to a hardened state on exposure to moisture. U.S. Patent No. 5,228,164, incorporated herein by reference, describes a knitted fabric material impregnated with a water curable polymer resin that is suitable for use in making the beanie cap 10 of the present invention. Alternatively, a suitable knitted polyester fabric material for making the beanie cap 10 is available by Carolina Narrow Fabric Company (Winston Salem, NC). The fabric is impregnated with a water-curing urethane polymer. The water curable polymer cures slowly when exposed to moisture in the air, or rapidly if water is applied directly to it. Additionally, other suitable curable polymeric materials can be used in the beanie cap 10 according to the invention, and such materials can be selected by a person having ordinary skill in the art without undue experimentation. For example, other light or heat curing polymer resins can be used.

[0029] As supplied, the beanie cap 10 has a generally tubular structure that is open at one end and terminates at the other end in a closed, substantially dome shape portion 12 as evident from Fig. 1. Most preferably, the beanie cap 10 has a continuous knitted structure with no seams. In a preferred embodiment illustrated in Fig. 1, the beanie cap 10 has a substantial portion of its tubular length rolled up into a roll 14 that is disposed circumferentially about the dome shape portion 12 of the beanie cap 10. In this embodiment, the beanie cap 10 is easily and uniformly snugly applied over and against a wearer's head by first aligning and placing the dome shape portion 12 against the apex of the head, and then with the dome shape portion 12 held in place, unrolling the tubular portion of the beanie cap 10 from the roll 14 over the head 20 such that the beanie cap 10 extends downward from the dome shape portion 12 against the surface of the wearer's head 20. This process is best illustrated in Fig. 2. It will be apparent from Fig. 2 that it is not necessary that the beanie cap 10 be unrolled an equivalent length all the way around; i.e. it may be necessary to unroll

a portion of the beanie cap 10 to a greater extent adjacent the rear and side portions of the head 20 than adjacent the forehead to ensure complete and effective head shape coverage. This is expected and intended in the present invention, and such uneven stretching/unrolling of the beanie cap 10 is accommodated by the elastic property of the beanie cap material as described above. The beanie cap 10 must be unrolled or pulled down over the head sufficiently in every direction to match the head coverage of the energy-absorbing liner that will be molded using the headform to be made by curing the polymer impregnated in the beanie cap 10 (described below). The location of the eyebrows, the ears, the occipital ridge, the centerline of the head and the fore and aft horizon of head with person looking forward preferably are marked on the beanie cap 10.

[0030] Alternatively, the beanie cap 10 is provided having no such roll 14, such that its tubular length is not rolled up. In this embodiment, the beanie cap 10 is stretched over the wearer's head, and after it is tightly fitted, a terminal portion of the tubular length of the cap may be folded up or back on itself so as not to cover the wearer's eyes and to facilitate removal of the hardened headform once it is complete.

[0031] Once the beanie cap 10 is stretched snugly over the contour of the wearer's head 20, the coated or impregnated polymeric material of the beanie cap 10 is cured or allowed to cure to yield a hardened headform 60 from the beanie cap, in the shape and contour of the wearer's head 20. When the preferred water curable resin is used, the beanie cap 10 preferably is submerged or dipped once into warm water to initiate the curing process prior to applying the beanie cap to the wearer's head. Additionally, hot water can be sprayed onto the beanie cap 10 once it is applied to the head to further accelerate curing. Water vapor or ambient moisture also can be used but will result in a slower-rate cure, which may be desirable in some applications, e.g. if minor adjustments are to be made to the beanie cap against the wearer's head as the cap is cured.

[0032] After the headform 60 has hardened, it is carefully removed from the head and used in subsequent molding operations described below. To remove the hardened headform it is generally necessary to cut the headform (e.g. with scissors) adjacent the back of the head to facilitate removal. If desired, a piece of flexible tubing 15 such as polyethylene tubing can be placed along the centerline of the rear of the person's head as a scissor guide prior to fitting the beanie cap 10 over the head. (Fig. 3) The tubing 15 can be held in place by any suitable means, e.g. by strips of tape 16 as shown in the figure. The flexible tubing 15 aids cutting the hardened headform for removal once the curable resin has cured and hardened without risking cutting the hair or the scalp. Therefore, the tubing 15 extends at least partially below the terminus of the

beanie cap 10 when unrolled against the rear of the head 20. If used, preferably the tubing 15 has an outer diameter of about or less than ½ inch, preferably ¼ inch, preferably 1/8 inch, so as not to substantially interfere with the beanie cap 10 being snugly fitted to the head 20. Because the tubing 15 is flexible, it can be compressed by the beanie cap 10 thereby further reducing the tubing's impact on the snugness of the beanie cap fit. Alternatively, instead of plastic tubing 15, a flat piece of flexible plastic or plastic strip can be used as a scissor guide. When the plastic strip is used, it is affixed (i.e. taped) against the wearer's head, preferably beginning above the occipital ridge, such that it extends downward to just below the lower terminus of the beanie cap 10 as applied to the head. When the plastic strip is used, the rear side of a scissor blade is guided along its length when making the scissor cut such that the strip protects the wearer's head (and barrier 30 if provided) from being cut by the scissors. Once the headform is removed, the two edges of the scissor cut are rejoined and fastened by staples or super glue, or other suitable fastener. As a further alternative, a zipper can be provided in the beanie cap such that once the cap is hardened to produce the hardened headform, the zipper is simply unzipped to permit removal of the headform from the head.

[0033] Because the beanie cap 10 is coated or saturated with a polymeric resin, it is desirable to place a barrier over the wearer's head 20 prior to fitting the beanie cap 10 thereover. Such a barrier 30 is shown schematically in Fig. 3, and can be in the form of a plastic film or sheet that has a thickness of less than about 2 mm, preferably less than about 1 mm or 0.5 mm. Latex films generally are water impermeable, and so these are desired for the barrier 30 when a water cured resin is used in the beanie cap 10 to prevent the wearer's head and hair from getting wet with resin and/or water. In addition, latex also is substantially impermeable to the polymeric resins used in the invention and are also desirable for this reason. However, the barrier also can be made from other suitable materials, such as plastic films or even fabrics, so long as the material used will prevent or substantially prevent penetration of the curable resin and contact of the resin with the wearer's head. It is not necessary that the fabric be impermeable to the resin material; so long as it will not become saturated with the resin in the time it takes to complete the headform making process, the barrier 30 will provide adequate protection for the wearer's head. Preferably, the barrier 30 will cover the person's eyes, nose, and a substantial portion of the neck in order to shield the person from contact with the urethane or other resin.

[0034] Preferably, the barrier 30 has an elastic or stretchy property so it can be snugly and tightly fit against the wearer's head in order to minimize or prevent spacing defects between the finished headform 60 and the wearer's head. Once the barrier 30 is in place, the beanie cap 10 is

placed over the head 20 (and over barrier 30) and the process is completed as described above. To protect the person being fitted from water, a smock or protective covering should be worn. Gloves should be used when fitting the beanie since the resin will stick to hands and can cause irritation.

[0035] Figs. 4-6 illustrate a heat-softenable plastic sheet 40 according to the invention as well as the method of application to a wearer's head 20. Preferably, the plastic sheet 40 is a heat-softening thermo-forming plastic sheet such as Polyform™ available from Sammons Preston Rolyan (formerly Smith & Nephew), Bolingbrook, IL. Most preferably, the plastic sheet 40 is 1/16 inch or 1/8 inch thick, however other suitable thicknesses may be used. As shown most clearly in Fig. 4, the plastic sheet 40 is cut into the shape of a crude flower with between 3 and 10 "petals" or elements 42. The crude flower shape is designed so that the plastic sheet 40 can be fitted adjacent its geometric center against the apex of the wearer's head 20 (see Fig. 5) with individual elements 42 folded or draped down over and against the wearer's head (Fig. 6). In the illustrated embodiment, four elements 42 are shown extending generally outward from the center-most portion of the sheet 40: a frontal element 43, rear element 44, and left and right lateral elements 45 and 46 respectively. The frontal and rear elements 43 and 44 each have a plurality of laterally extending tabs 48 which are used to aid fixing the sheet 40 in the shape and contour of the head 20 as will be further described. Alternatively, other appropriate shapes for the plastic sheet 40 can be used.

[0036] Initially, the heat-softenable plastic sheet 40 is heated above its softening temperature, typically to 65-70°C. Once softened, the heated plastic sheet 40 is draped over the head as described above and shown in Figs. 5-6. To protect the forehead and ears from the heat and to keep the plastic from sticking to the hair, a thin bathing cap or a plastic film (barrier 30) should be placed over the head before the heat-softened sheet 40 is applied. The plastic sheet 40 is pressed against the head in its softened state, e.g. by hand, and is held against the head until the plastic cools below its softening temperature and re-hardens. Once the plastic sheet 40 has been fitted and the individual elements 42 draped over and against the wearer's head, the laterally extending tabs 48 from the frontal and rear elements 43 and 44 are pressed against adjacent the lateral elements 45 and 46 to aid and define the shape of the plastic sheet 40 conforming to the wearer's head as the plastic cools and hardens to yield the hardened headform 60 conforming to the shape and contour of the wearer's head. If desired, a piece of flexible tubing can be used similarly as for the stretchable beanie cap described above as a scissor guide to aid removal of the hardened headform.

[0037] Fig. 7 illustrate a preferred method of using a curable tape 50 to provide the hardened headform. Using curable tape to define the head shape is more time consuming and

requires a skilled technician to apply the strip(s) of curable tape 50 properly. In this embodiment, the curable tape 50 preferably is provided in the form of a strip or strips of compliant material, such as fabric or other textile material or synthetic material, that is/are coated or impregnated with a curable polymeric material. Similar curable materials and/or resins can be employed as in the beanie cap embodiment. The compliant material preferably is made from glass fabric (such as fiberglass) for optimal stiffness, and is coated or impregnated with the curing resin. The curable tape 50 also can be made of a knitted thick, but porous, fabric or a bias cut fabric, including synthetic fabrics. If fabrics are used they must be thick enough to provide "section" but porous enough to allow permeation of the water necessary for curing when a water curable resin is used. A tape having a width of about 3-4 inches is preferred, noting it takes approximately 700 square inches to complete a head. A suitable resin-impregnated complaint fabric tape is 3M Scotchcast™ Plus Casting Tape (3M Health Care, St. Paul, MN.), which is a knitted fiberglass fabric impregnated with a water-curable polyurethane resin. Alternatively, the curable tape 50 can be made from a strip or strips of curable polymeric material, such as strips of yet uncured polyurethane which can be hardened e.g. by contacting with water.

[0038] The tape 50 is wrapped around the head 20 as shown in Fig. 7, being careful to get the tape low enough so that the full head-contacting surface for the energy-absorbing liner for the helmet is defined. Just as in the above-described embodiments, a barrier 30 can be and preferably is employed to prevent or minimize contact of the resin or curing water with the wearer's hair or scalp. In this embodiment, the barrier 30 can be used in addition as a guide to indicate how far down on the head the tape 50 should be applied. As with the beanie cap, gloves should be used when applying the tape 50 and smock or a protective covering should be worn to protect the person being fitted. In the preferred embodiment, when the tape 50 is coated with a water curable resin, the tape is initially squeezed or wrung in warm water to begin the curing process, and is then wrapped quickly around the perimeter of the head, cut, and several layers are placed over the top of the head, so that the head is fully covered. A final wrap is made around the head just above the initial wrap to ensure that there are no gaps. The tape is gently wiped downward and pressed against the head until the tape hardens. When using the preferred water curing resin, the tape cures in less than 10 minutes when water is applied, yielding the hardened headform 60.

[0039] Because the resin will cure (and consequently the tape will rigidize) quickly after being immersed in water, a skilled technician will be required to apply the tape properly before it has rigidized. In this embodiment, a certain level of practice is anticipated on the part of the

technician to develop a sufficiently rapid wrapping technique.

[0040] Irrespective of which of the above shape-forming means is used to provide the hardened headform, care must be taken to cover the proper amount of the head so that the subsequently formed energy absorbing liner (molded from the headform, or whose mold is made using the headform as described below) complies with the proper coverage standards and suitably covers the appropriate portions of the head. For example, for motorcycle helmets, the highest coverage standard is Snell M2000 or DOT FMVSS 218, for football helmets it is ASTM F429-01 or NOCSAE Doc. 002-96m98, and for bicycle helmets it is ASTM F1447-99a or CPSC Prt. 1203.

[0041] Also irrespective of which of the above shape-forming means is used to provide the hardened headform, preferably a clearance is provided to position a thin layer of foam spacer or spacer(s) to allow for air circulation, as well as the aesthetic lining or upholstering material that will cover all or part of the inside surface of the helmet. This clearance can be provided by placing a tight fitting elastic hood 65 as seen in Fig. 8 having a hood thickness over the head prior to applying the shape-forming means thereover. The hood thickness preferably is approximately 1/8 to ¼ inches. This will result in the subsequently formed impact energy absorbing liner having a larger interior dimension, providing the clearance for the foam spacers for air circulation. An alternative method is to create the clearance on the "male" member of the liner mold (described below) by covering it with wax or stretchable material (such as silicone or latex material), or another material with the proper thickness that will provide the necessary clearance.

[0042] Once the hardened headform has been made using any of the shape-forming means described above, it can itself be used as the "male" member, together with a suitable "female" member, of a mold for molding the impact energy absorbing liner for the helmet. Alternatively, the hardened headform can be used as a mold cavity (previously occupied by the wearer's head) into which plaster or some other molding compound is poured, which will itself harden and then will be used as the "male" member of the mold for making the energy absorbing liner. Each of these methods is now described with respect to Fig. 9.

[0043] In the first method, where the headform is itself used as the "male" member 102 of the mold, the headform is positioned adjacent and spaced a distance from the concave inner surface 104 of a "female" mold member 103 such that the exterior surface 105 of the headform and the inner surface 104 of the "female" mold member define a molding space 108 therebetween for molding the energy absorbing liner. The molding space 108 will have very close to the same

dimensions as the finished impact energy absorbing liner as will become evident. When using the hardened headform 60 as the "male" member 102 of the mold, the exterior surface of the headform is sanded to eliminate defects such as exterior bumps, ridges, and wrinkles. Any holes in the headform also should be tightly taped both inside and out so that the expanding foam will not cause them to depress. Typically, the headform is then filled with a hardening material and a pipe or other handle is suspended in the hardening material until it is hardened. The pipe/handle allows the headform to be held and articulated. A layer of stretchable plastic or rubber may be stretched over the headform to create clearance for inserting foam spacers for air circulation if the wearer's head was not previously provided with an elastic hood 65 to provide such clearance as described above.

[0044] In the second method, Plaster of Paris (preferred) or other suitable plaster or curable/hardening material is poured or provided in its uncured state into the cavity defined by the hardened headform, and is then cured to provide a male fixture in the shape of the wearer's head from which the headform was made. In order to prepare the headform to cast the male fixture from plaster or other suitable material, it is important first to seal the headform with an appropriate sealant to make it water tight. If desired, a pipe or other handle structure can be inserted into the yet-uncured Plaster of Paris material and suspended in place until the plaster dries to facilitate handling and fixturing. When the plaster has cured, the hardened plaster fixture is removed from the headform and is lightly sanded to smooth and to remove ridges and irregularities. If the headform was hardened over the wearer's head without the elastic 1/8 inch to ¼ inch thick hood 65 in place (see above and Fig. 8), it may be necessary to provide a clearance for the foam spacers to be positioned between the energy absorbing liner and the wearer's head in the finished helmet. A tight fitting urethane film, or a latex or silicone cover is believed to work effectively. In any case, the surface that is exposed to the foaming composition (described below) should be coated with a release coating so that the foam of the energy absorbing liner will not stick to it once cured.

[0045] The "female" mold member 103 can be a conventional female mold member having a cavity 110 for molding foam or other resinous energy absorbing materials, e.g. as shown in Fig. 9. Alternatively, the "female" mold member can be the outer helmet shell into which the liner ultimately is to be placed. In this embodiment, the liner is formed in situ, directly in the helmet shell and can bind to the inner surface of the shell as it cures.

[0046] Returning to Fig. 9, a schematic representation of an energy absorbing liner forming operation is portrayed. While this schematic is shown having a conventional "female" mold member having cavity 110, it will be understood that the principal of operation as displayed and

further described will not be substantially different when liner is formed directly into the outer helmet shell. In addition, "male" member 102 in Fig. 9 schematically portrays the male member of the mold which conforms to the shape of the wearer's head for which the liner is being cast, and can be either the hardened headform or a plaster fixture made from the headform as above described. The apparatus shown in Fig. 9 is similar to the structure of a Bridgeport milling machine, having a table 180 that is universally adjustable to provide precise alignment and adjustability between the "female" mold member 103 on the table, and the "male" mold member 102 suspended above.

[0047] To make the energy absorbing liner, the "male" member 102 is positioned such that its exterior surface 105 is located adjacent and spaced apart a distance from the concave inner surface 104 of the "female" mold member 103, such that the exterior surface 105 of the "male" member 102 and the inner surface 104 of the "female" member 103 define a molding space 108 therebetween having a substantially spheroid shape. To ensure uniformity of the spheroid molding space, the "male" member 102 and mold cavity 110 can be assembled to a press 150 as shown in Fig. 9, where the "male" member 102 is mounted to a retractable shaft that is adapted to centrally align the "male" member with the mold cavity 110. Alternatively, other conventional or suitable alignment mechanisms may be employed.

[0048] Next, a curable compound is provided or injected into the spheroid molding space 108 to substantially fill that space, and is cured or allowed to cure to form the desired impact energy absorbing liner. Most preferably, the curable compound is a liquid foam precursor composition that cures and expands to form an energy absorbing foam.

[0049] The most preferred foam is a semi-rigid viscoelastic foam made from a two-part foaming composition, preferably, one part being isocyanate and the other part being a polyol or mixture of polyols. Most preferably, the foam is Zorbium™ foam available from Team Wendy, LLC in Cleveland, Ohio. Zorbium™ is an energy-absorbing foam that, unlike expanded polystyrene (EPS), exhibits substantially 100% crush recovery following an impact, yet it is still effective to absorb low to high energy impact forces (i.e. 2 to 4 as well as 4 to 7 m/sec, or anywhere in between) and dissipate much of the impact energy away from the head at the localized region of impact. Zorbium™ crushes more than EPS under low speed impacts, and yet has approximately the same crush as EPS under high speed impacts – it thus provides greater impact protection over a wider range of impact velocities. Less preferably, other known or conventional impact energy absorbing foams or resins can be used, such as EPS or expanded polypropylene (EPP), vinyl nitrile,

etc. Generally, when molding EPS or EPP steam is used to heat the precursor polystyrene/ polypropylene beads. As the beads soften the soluble hydrocarbons expand to generate the foam. Therefore With EPS or EPP, the mold should be provided with a number of vent holes to permit venting of the steam.

[0050] The thickness and density of the impact energy absorbing liner (preferably made from foam, preferably Zorbium™ foam) depend on a variety of factors, perhaps most importantly the anticipated or probable impact velocities, the composition of the outer helmet shell and the site and vector of probable impacts. Arriving at the precise foam composition and thickness for the impact energy absorbing liner involves matching the stiffness and strength of the outer shell with the stiffness of the foam taking into account the most critical impact velocities and vectors.

[0051] It is preferred to utilize the plaster fixture made from the hardened headform as the "male" mold member 102 because this fixture more accurately conforms to the shape and size of the wearer's head 20 because it is cast in the same cavity once occupied by the head. Using the headform 60 directly as the "male" member 102 of the liner mold is faster (omits a step) than making and using a plaster fixture, but is less precise and can result in greater irregularity in the finished foam liner. But even if this technique is used it may be necessary in some cases to stretch an elastic material over the headform as described to allow for more clearance for the foam spacers for air circulation in the helmet.

[0052] In a preferred configuration the "female" mold member 103 splits into four sections as shown in Fig. 9 that slide out allowing precise measurement of the molding space between the "male" member 102 and the inner surface 105 of "female" member 103. It will be understood that proper thickness and shape of this molding space 108 is important, because there is a minimum foam thickness for the energy absorbing liner that is necessary for effective impact absorption. It is critical that the mold not be cocked to either side or front to back during molding. On the "male" member 102, markings are made for the eyebrows, the position of the nose, for the position of the occipital ridge and for the fore and aft horizon of the wearer. Most preferably, these markings are made on the hardened headform 60 prior to removal from the wearer's head to precisely locate these features for the particular wearer. Alternatively, if a plaster fixture is made from the headform, these markings are transferred to the fixture as it is demolded from the headform. These markings will describe where the head will be positioned in the helmet, and help to align the "male" member to define the molding space.

[0053] It is important to pre-measure the volume to be foamed to fill the molding space 108. Most preferably, this is achieved by first measuring the volume of the female cavity 110, and then subtracting that portion of the "male" member 102 that is inserted into the cavity 110, whose volume can be determined by water displacement. Once the precise volume of the molding space 108 for the energy absorbing liner is known, the correct amount of the foaming compound can be mixed to achieve the proper density of the finished foam liner that will yield the proper energy-absorbing characteristics.

[0054] As shown in Fig. 10, once the "male" and "female" mold members 102 and 103 are in position defining the molding space 108 therebetween, a lid or collar 109 is placed at the opening of the female cavity 110 around the perimeter of the "male" member 102 to seal the molding space. The pre-measured foaming compound is then provided or injected into the molding space, e.g. through the collar 109. As the compound foams and expands, it fills the molding space and rises to meet the collar, and the collar is held into place rigidly until the foaming pressure has subsided. Once foaming is complete, the collar is removed and the mold disassembled to retrieve the finished impact energy absorbing foam liner having an inner surface substantially conforming to the shape and contour of the particular wearer's head. It is noted that according to the invention, the finished impact energy absorbing foam liner is made as one piece, and not from multiple pieces that are subsequently joined via welding or other means. It is a one-piece liner whose inner surface is substantially uniformly and continuously snugly fitted to the wearer's head when the wearer is wearing the helmet, thereby eliminated localized pressure points between the liner surface and the wearer's head.

[0055] This liner is then fitted into an outer helmet shell and is upholstered with fabric and leather as may be desired to provide a custom fitted helmet for the wearer. A thin layer of soft open cell foam spacer or spacers (conforming to the clearance thickness described above) is typically placed between the upholstery and the impact absorbing foam to provide a space for air circulation, and holes are drilled in the foam to facilitate ventilation. Alternatively, if the helmet shell is used as the "female" mold member 103, it will be understood the liner formed therein is not removed.

[0056] The present invention can be used to make an impact energy absorbing liner having an inner surface substantially conforming to the shape and contour of a particular wearer's head for a variety of different helmets used in different applications. In a preferred embodiment, the helmet for which the liner is made as described herein is a motorcycle helmet. Alternatively, the helmet can be a bicycle helmet, football helmet, hockey helmet, skiing helmet, skydiving helmet ,

equestrian helmet, or other sports helmet, a helmet for medical intervention for persons prone to seizures or unconsciousness (narcolepsy), industrial protection helmet (e.g. for manufacturing and construction workers), aircraft helmet including military airplane and helicopter pilot helmets, etc.

[0057] The invention includes a kit comprising all of the materials needed to make a hardened headform as described herein using the beanie cap 10. Preferably, the kit includes the resin-impregnated beanie cap 10, a protective barrier 30 (preferably latex or silicone), protective gloves, waterproof apron and cape to shield the wearer's body, serrated scissors for cutting the hardened headform, a scissor guide (preferably plastic tube or plastic strip), scissor cut resealing means (preferably super glue or stapler), adhesive tape, a level, a ruler, printed casting instructions and optionally an instructional video.

[0058] Although the hereinabove described embodiments of the invention constitute the preferred embodiments, it will be understood that modifications can be made thereto without departing from the spirit and cope of the invention as set forth in the appended claims.